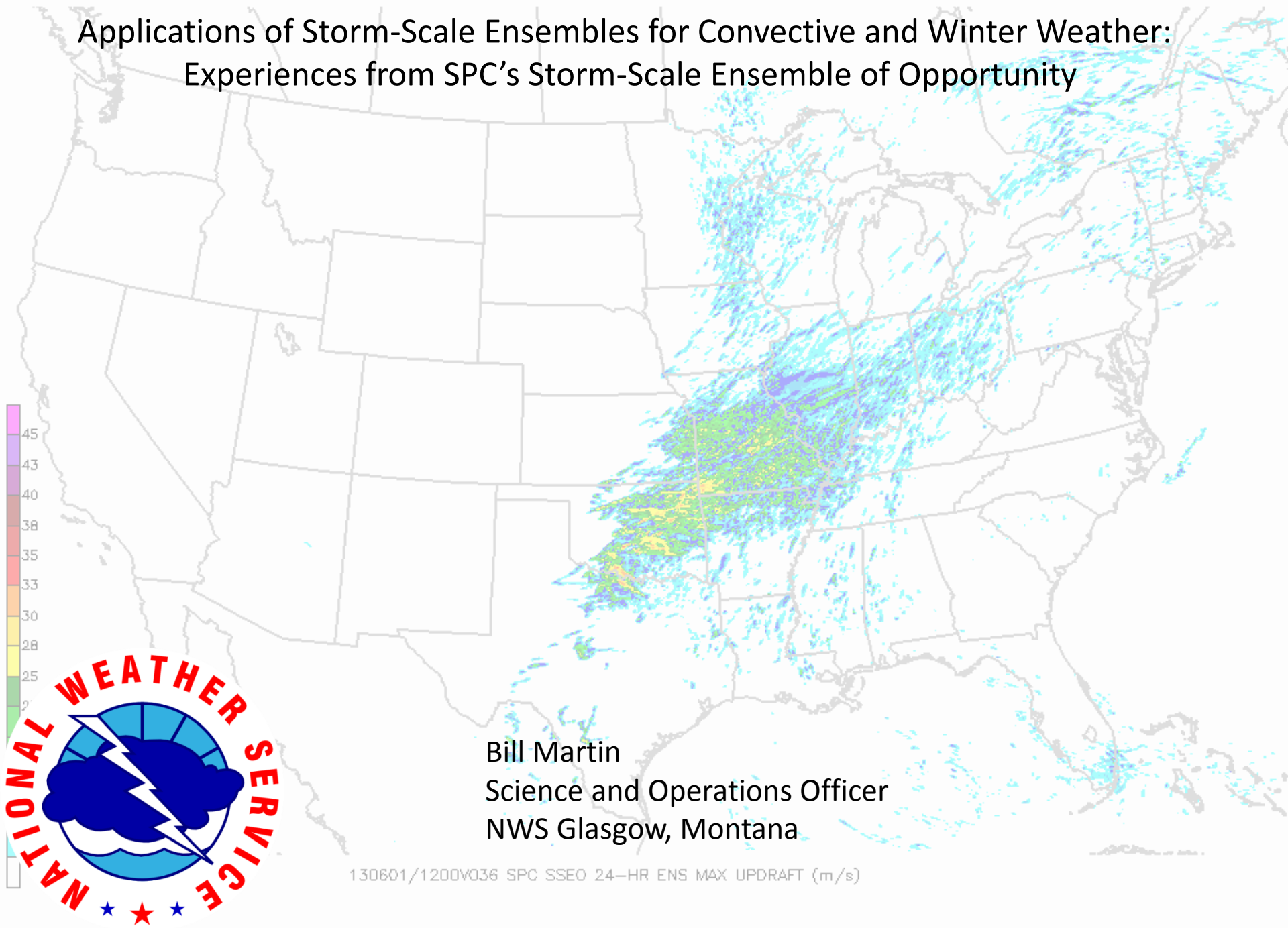


# Applications of Storm-Scale Ensembles for Convective and Winter Weather: Experiences from SPC's Storm-Scale Ensemble of Opportunity



This talk will focus primarily on experience using the  
Storm Scale Ensemble of Opportunity (SSEO) developed by the Storm Prediction:

Israel L. Jirak, Steven J. Weiss, and Christopher Malick, 2012: **The SPC Storm-Scale Ensemble of Opportunity: Overview and Results from the 2012 Hazardous Weather Testbed Spring Forecasting Experiment.** *Preprints* 26<sup>th</sup> Conf. Severe Local Storms, AMS P9.137.

This is an ensemble of 7 convection-resolving models from different sources (hence it is an “ensemble of opportunity”). This is because the cost of running the ensemble in house is prohibitive. Resolution is 4 or 5 km, with varying PBL and microphysics.

Models include versions of the WRF run at NSSL, EMC, and the 4 km NAM run at EMC.

Model initializations from 00Z each day are used, with forecasts out 36 hours. Thus, one new ensemble is available each day in the early morning.

Table of SSEO models used,  
from Jirak et al. (2012).

It is notable that these models do NOT have convective parameterization. Instead, they directly resolve storm structure. This is the main difference between storm-scale and non-storm-scale models.

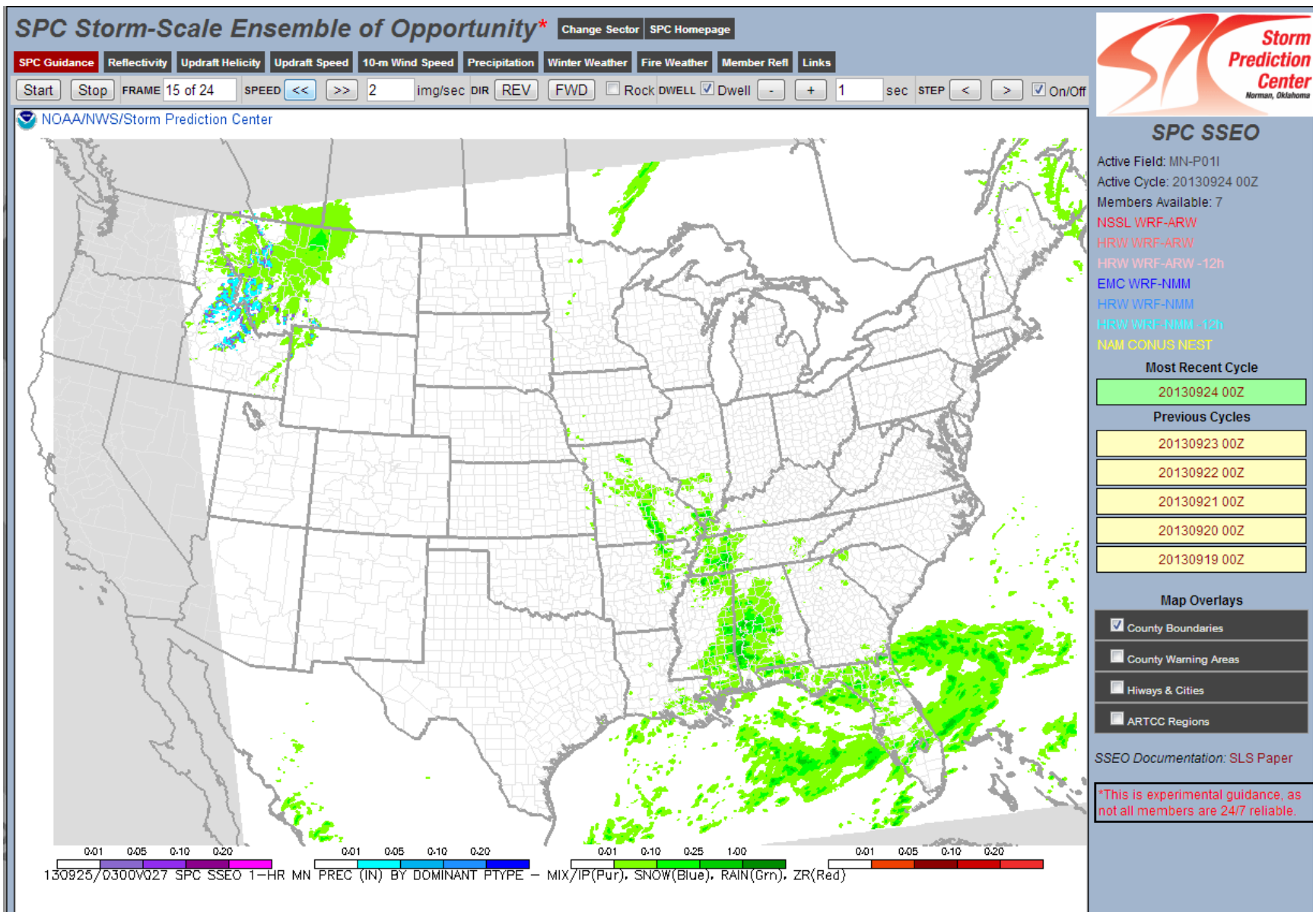
The PBL schemes also constitute LES schemes, which permit detailed structures in the boundary layer.

In a storm-scale model, PPT is a result of resolved storm dynamics, while in a non-storm scale model, PPT is a result of parameterization.

**Table 1: Membership configuration of the 00 UTC SSEO.**  
Members highlighted with an asterisk (\*) are 12-h time-lagged members.

|                             | Grid<br>Spacing | Vert<br>Levels | Time<br>Step | Fcst<br>Length | PBL | Micro   |
|-----------------------------|-----------------|----------------|--------------|----------------|-----|---------|
| NSSL<br>WRF-<br>ARW         | 4 km            | 35             | 24 s         | 36 h           | MYJ | WSM6    |
| EMC<br>HRW<br>WRF-<br>ARW   | 5.15 km         | 35             | 30 s         | 48 h           | YSU | WSM3    |
| EMC<br>HRW<br>WRF-<br>ARW*  | 5.15 km         | 35             | 30 s         | 48 h           | YSU | WSM3    |
| EMC<br>HRW<br>WRF-<br>NMM   | 4 km            | 35             | 7.5 s        | 48 h           | MYJ | Ferrier |
| EMC<br>HRW<br>WRF-<br>NMM*  | 4 km            | 35             | 7.5 s        | 48 h           | MYJ | Ferrier |
| EMC<br>CONUS<br>WRF-<br>NMM | 4 km            | 35             | 7.5 s        | 36 h           | MYJ | Ferrier |
| EMC<br>CONUS<br>NAM<br>NEST | 4 km            | 60             | 8.9 s        | 60 h           | MYJ | Ferrier |

SPC SSEO webpage showing domain (white area).



Ensemble graphics are produced by combining all 7 runs. 3 ways of doing this are provided:

- Ensemble Maximum plots: Shows the strongest feature values at each grid point from all models.
- Spaghetti plots: overlays single contours from all models on one plot.
- Probability plots: calculates observed probability of getting certain forecast elements.

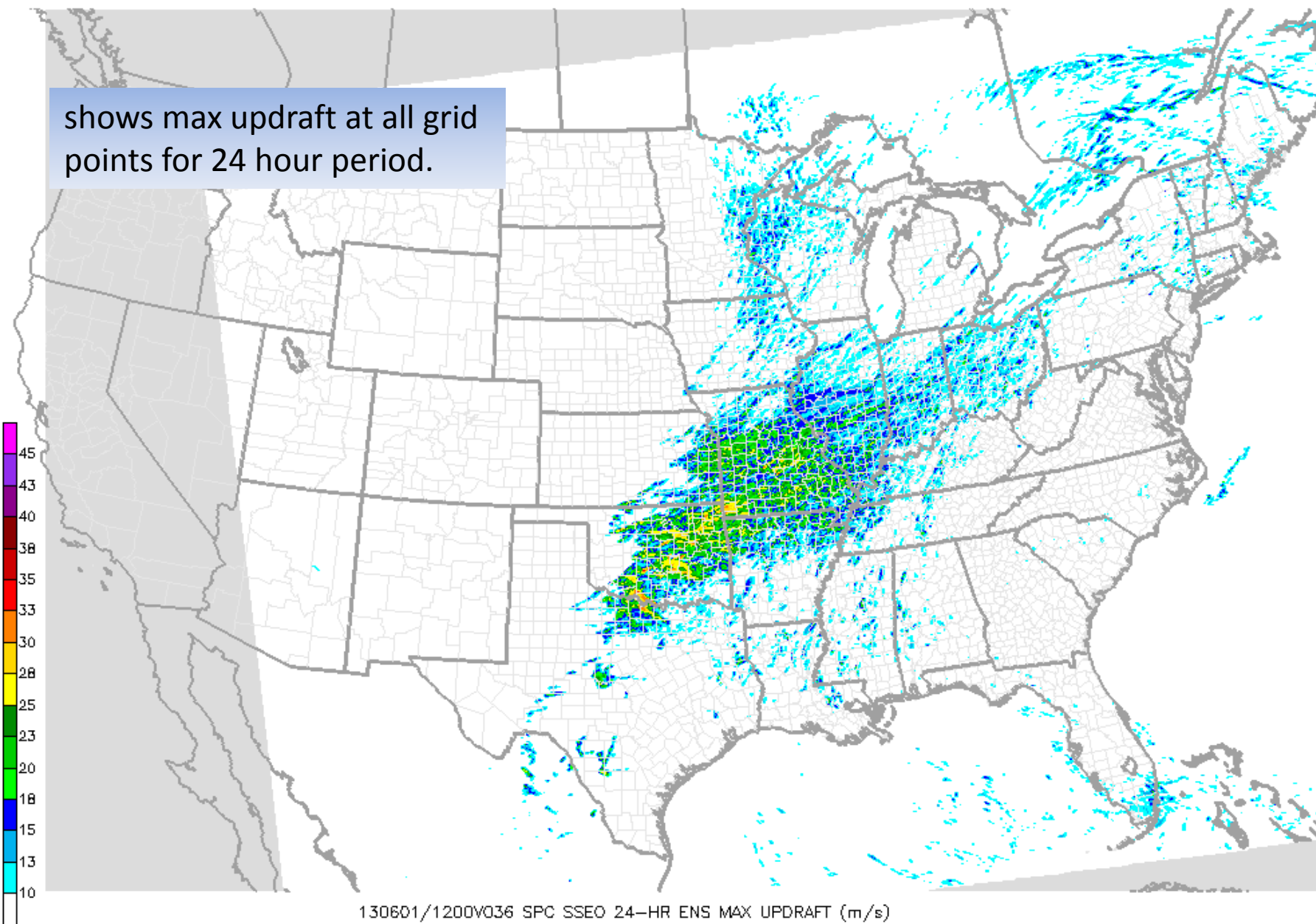
The above are available for **updraft**, **updraft helicity**, **10-m wind**, and **reflectivity**.

Sample Ensemble Max plot for June 1 2013 Forecast for MAX updraft (W).

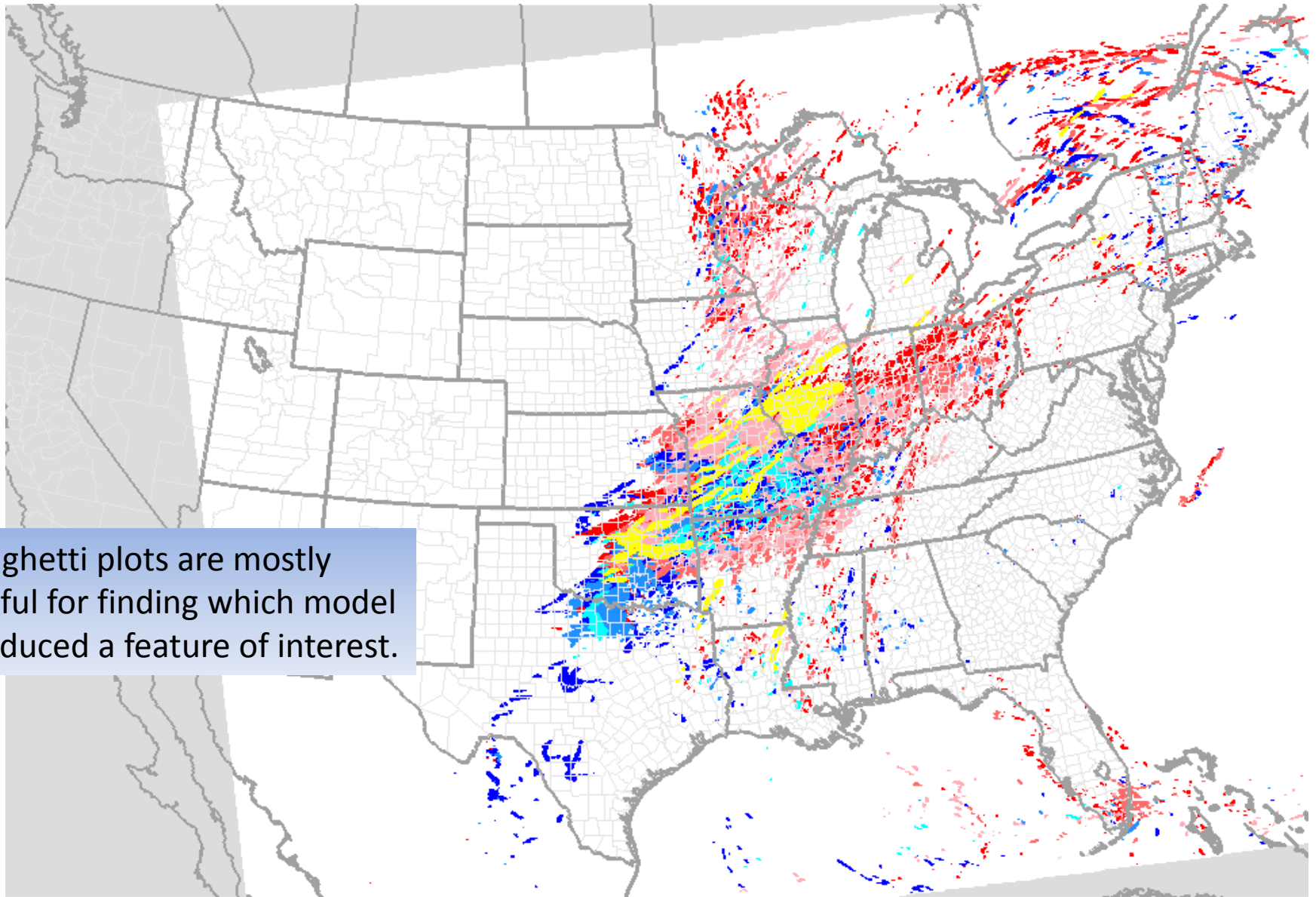
This image combines the strongest updrafts from all the models.

NOAA/NWS/Storm Prediction Center

shows max updraft at all grid points for 24 hour period.

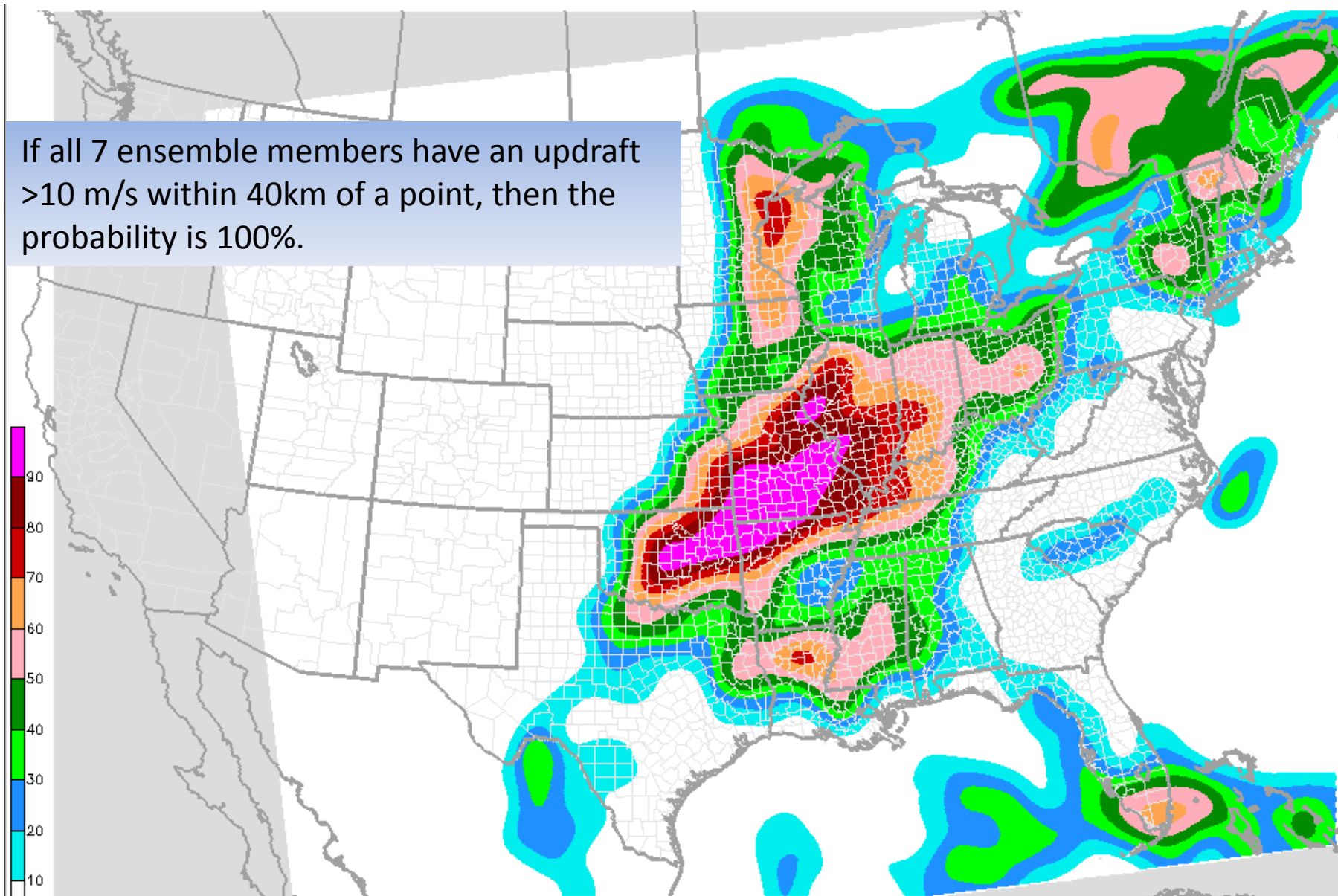


Sample spaghetti plot for June 1 2013 Forecast for updraft speed.  
Each color corresponds to one of the 7 runs.



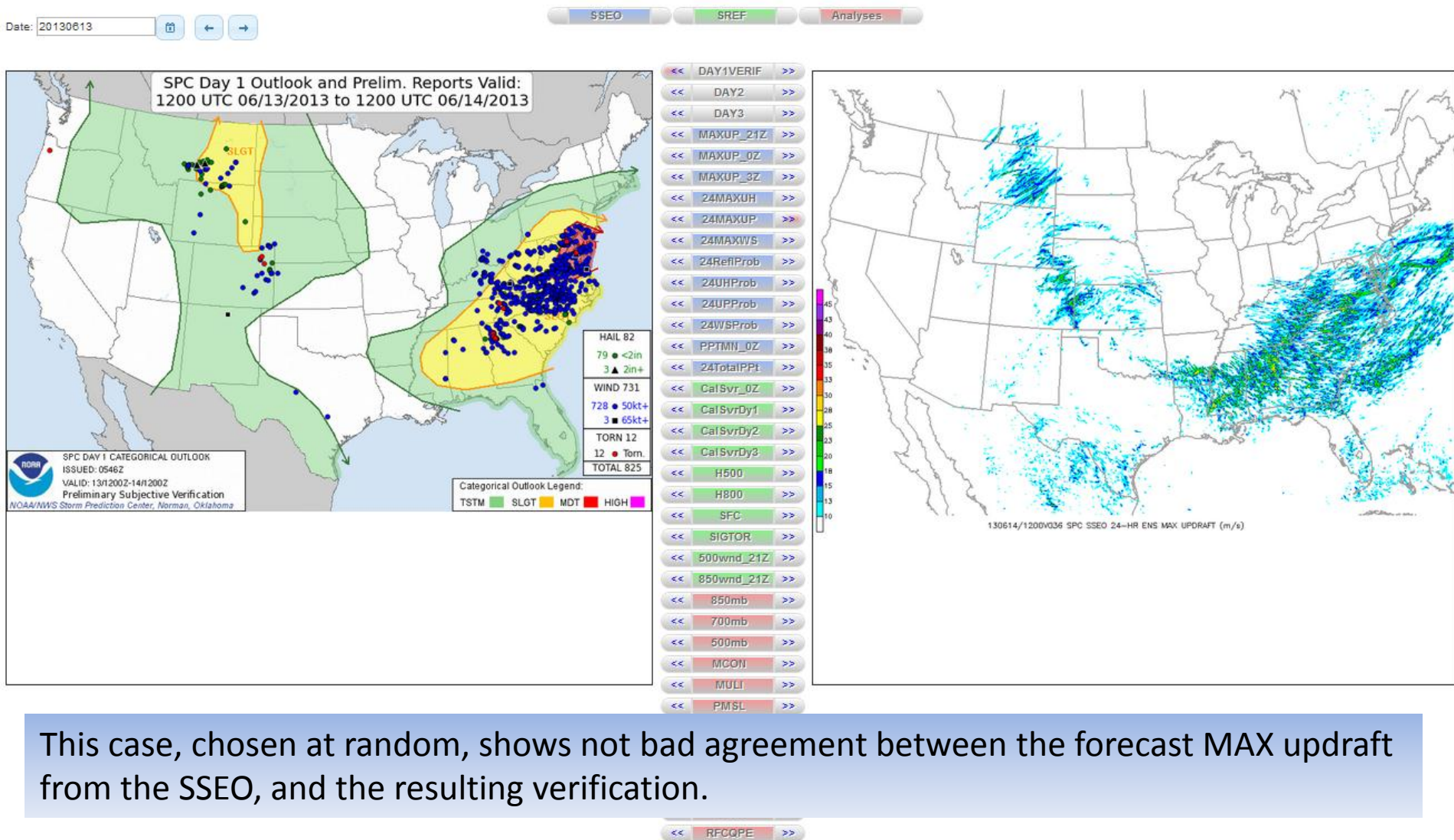
130601/1200V036 SPC SSE0 24-HR SPAG UPDRAFT >10 M/S

Sample Area Probability plot for June 1 2013 Forecast for Updraft Strength > 10 m/s.  
This shows the probability of getting an updraft > 10 m/s within 40 km of each point.



NWS Glasgow's verification comparator, which allows the rapid comparison of forecasts and verification of past events.

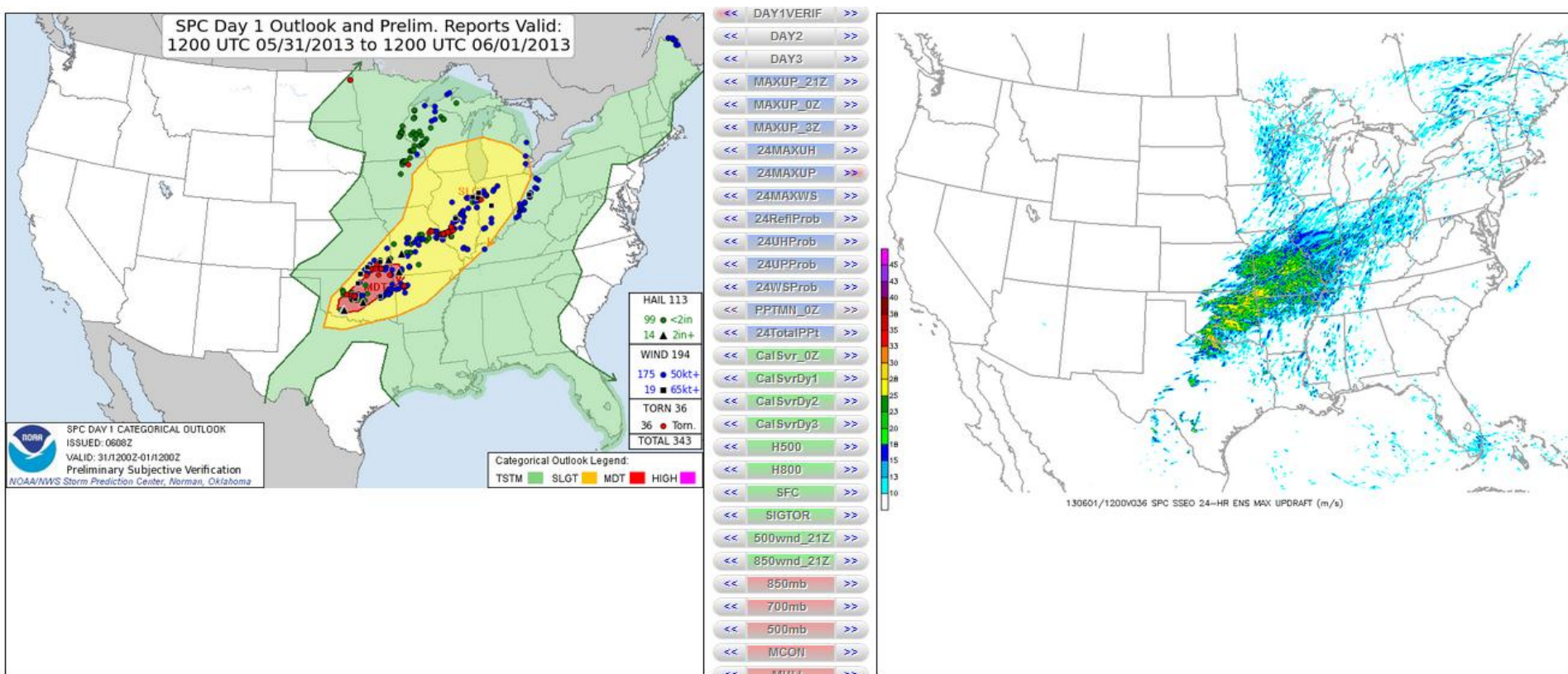
### SSEO/SREF Ensemble Convective Analysis and Verification Tool



This case, chosen at random, shows not bad agreement between the forecast MAX updraft from the SSEO, and the resulting verification.

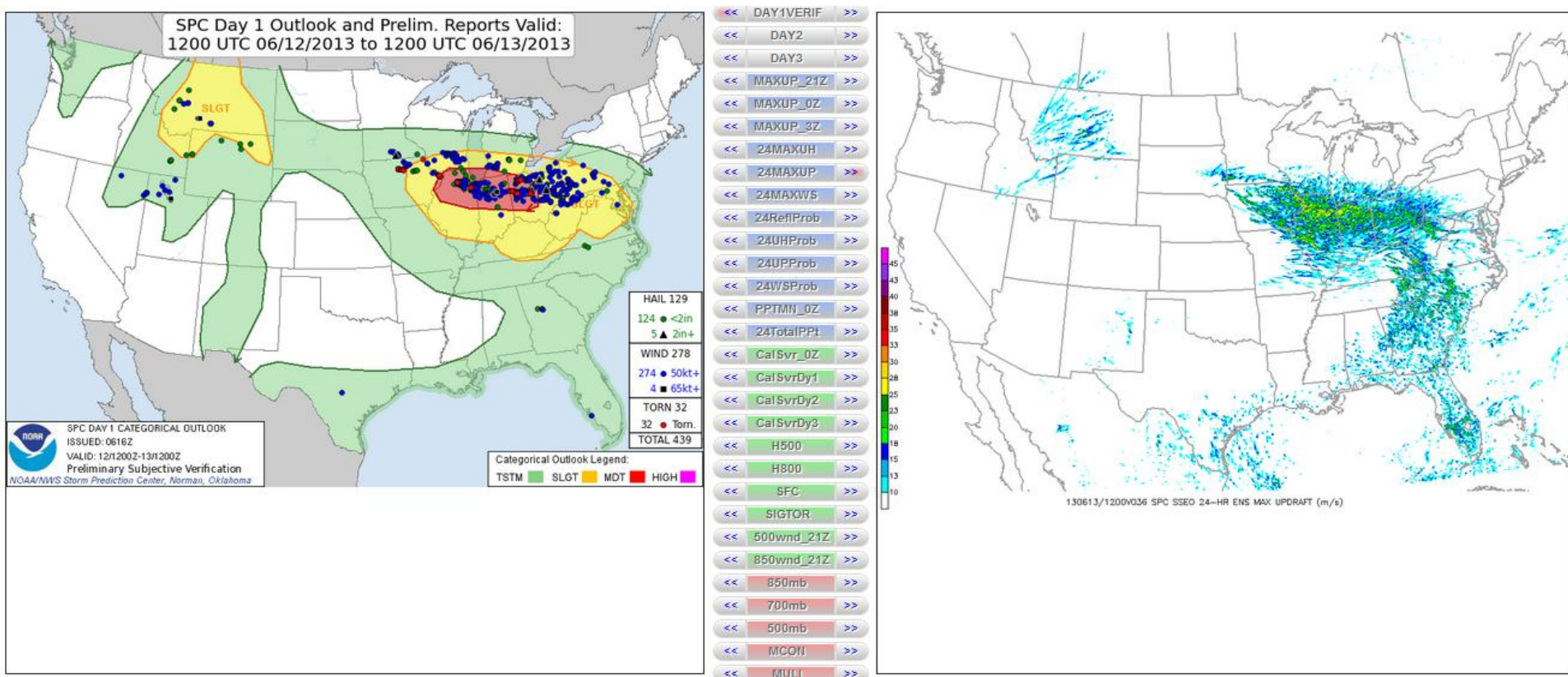
Most typically, we compare SSEO forecasts for the 24 hour period from 12Z to 12Z, with the severe weather reports received during that time, and the SPC DAY1 Outlook for that period issued at about 6Z.

Below was the forecast from 6/1/2013, which was a tornado outbreak day in Oklahoma, also well-forecast by the SSEO MAX updraft.



The Max Updraft (W) plots seem to be the best proxy for all kinds of severe.

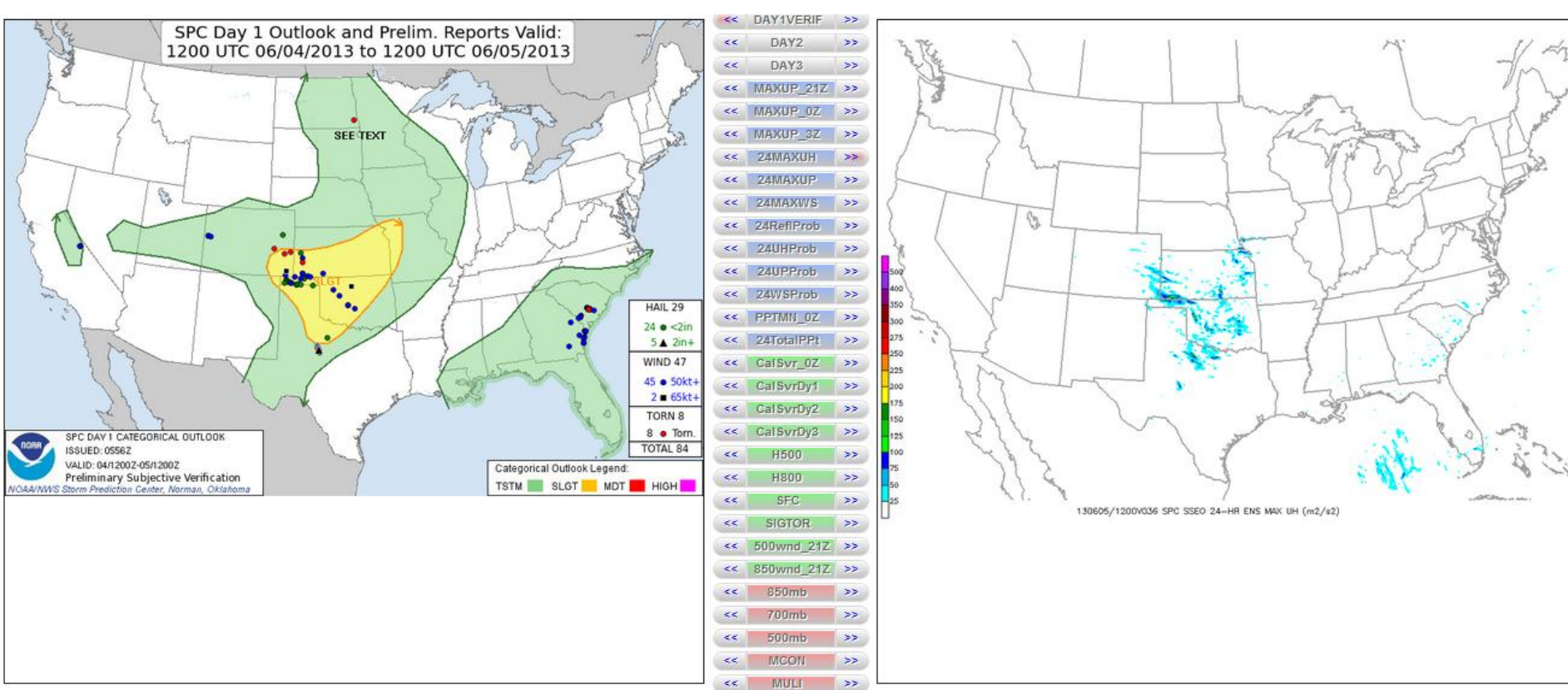
This example is for June 12, 2013.



The Max Updraft Helicity (UH) plots is a proxy for supercells/tornadoes.

In this case, reported tornadoes in SE Colorado verified area of MAX UH from the SSEO (a forecast with a lead of 36 hours).

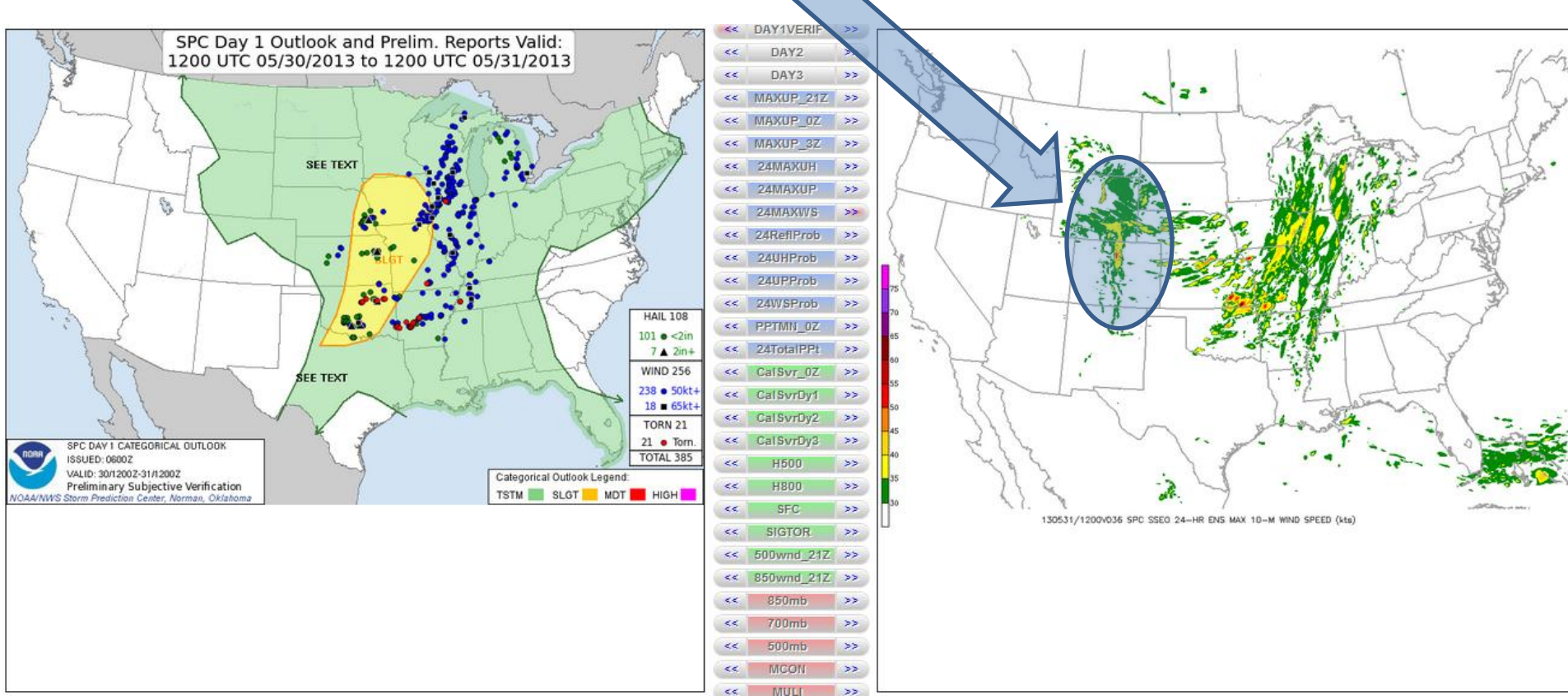
Tornado reports are problematic as it is common to get small tornadoes reported from otherwise benign systems (as in SE North Dakota here).



The Max 10-m Wind Speed is a proxy for severe straight-line winds at the surface.

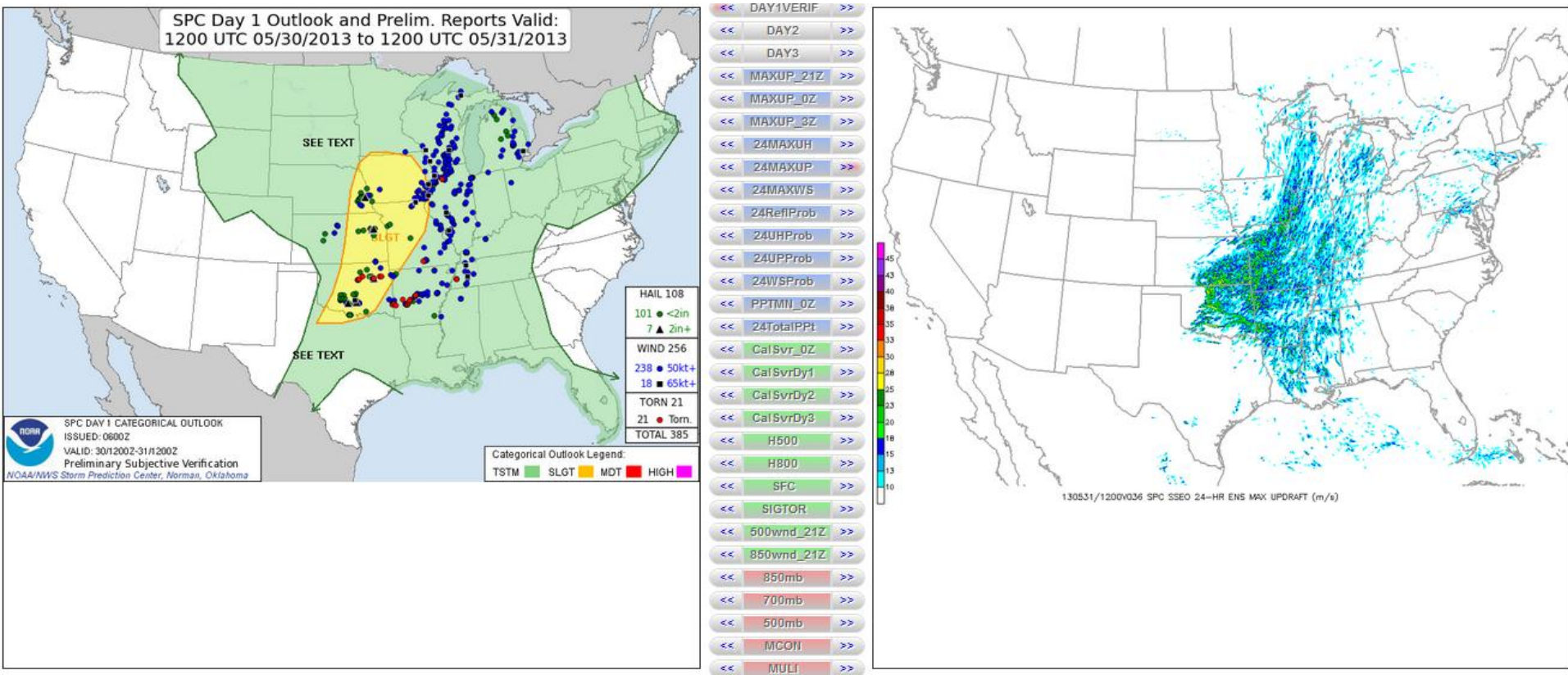
In this case, the SSEO Max 10-m Wind Speed predicts high winds over an area from Wisconsin to Arkansas that was missed by SPC.

However, it also shows high winds just east of the Rockies, and area that saw no convection.



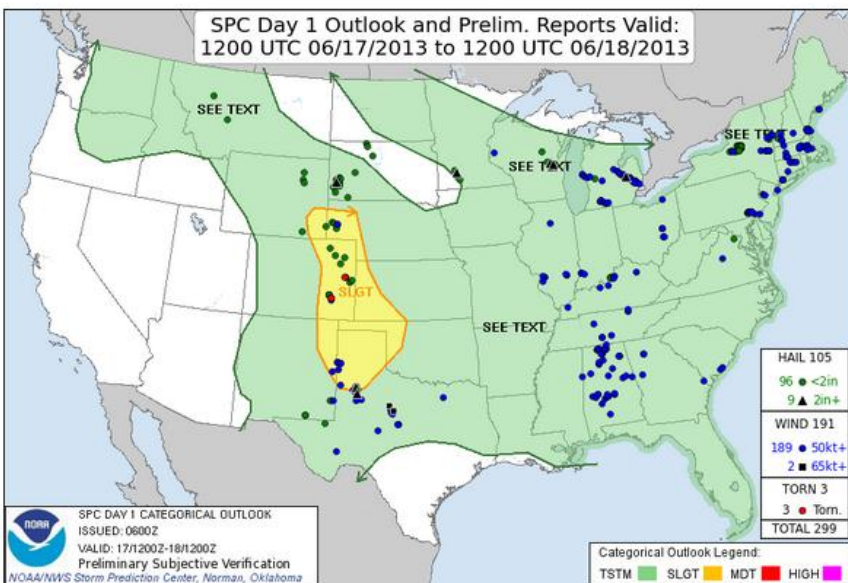
Same case as previous slide, but with MAX W, showing no convective updrafts just east of the Rockies.

Those winds were high winds from synoptic forces, unrelated to convection.



Most of the large misses by the SSEO are for cases with strong winds.

In this case, most severe wind reports were missed by the SSEO Max 10-m wind plot.



<< DAY1VERIF >>

<< DAY2 >>

<< DAY3 >>

<< MAXUP\_21Z >>

<< MAXUP\_0Z >>

<< MAXUP\_3Z >>

<< 24MAXUH >>

<< 24MAXUP >>

<< 24MAXWS >>

<< 24RefProb >>

<< 24UPProb >>

<< 24WSPProb >>

<< PPTMM\_0Z >>

<< 24TotalPPI >>

<< CalSvr\_0Z >>

<< CalSvrDy1 >>

<< CalSvrDy2 >>

<< CalSvrDy3 >>

<< H500 >>

<< H800 >>

<< SFC >>

<< SIGTOR >>

<< 500wnd\_21Z >>

<< 850wnd\_21Z >>

<< 850mb >>

<< 700mb >>

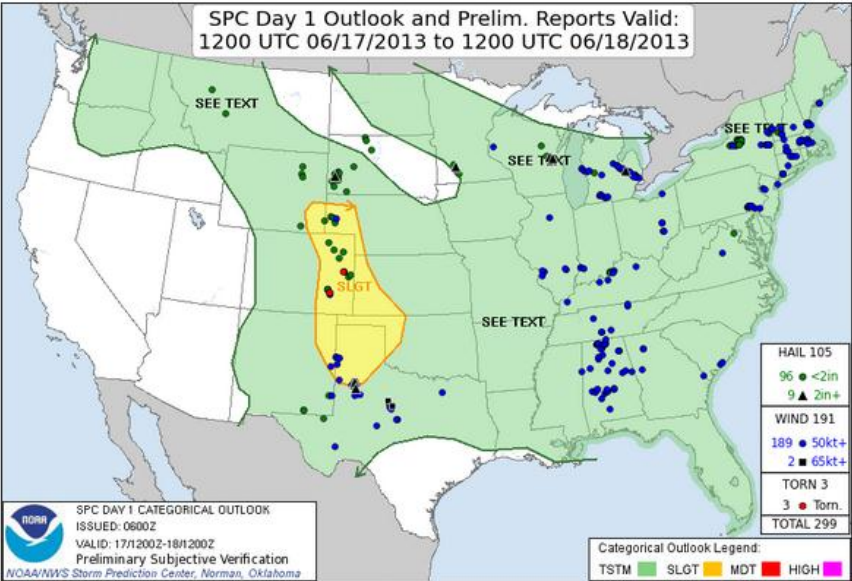
<< 500mb >>

<< MCON >>

<< MULI >>



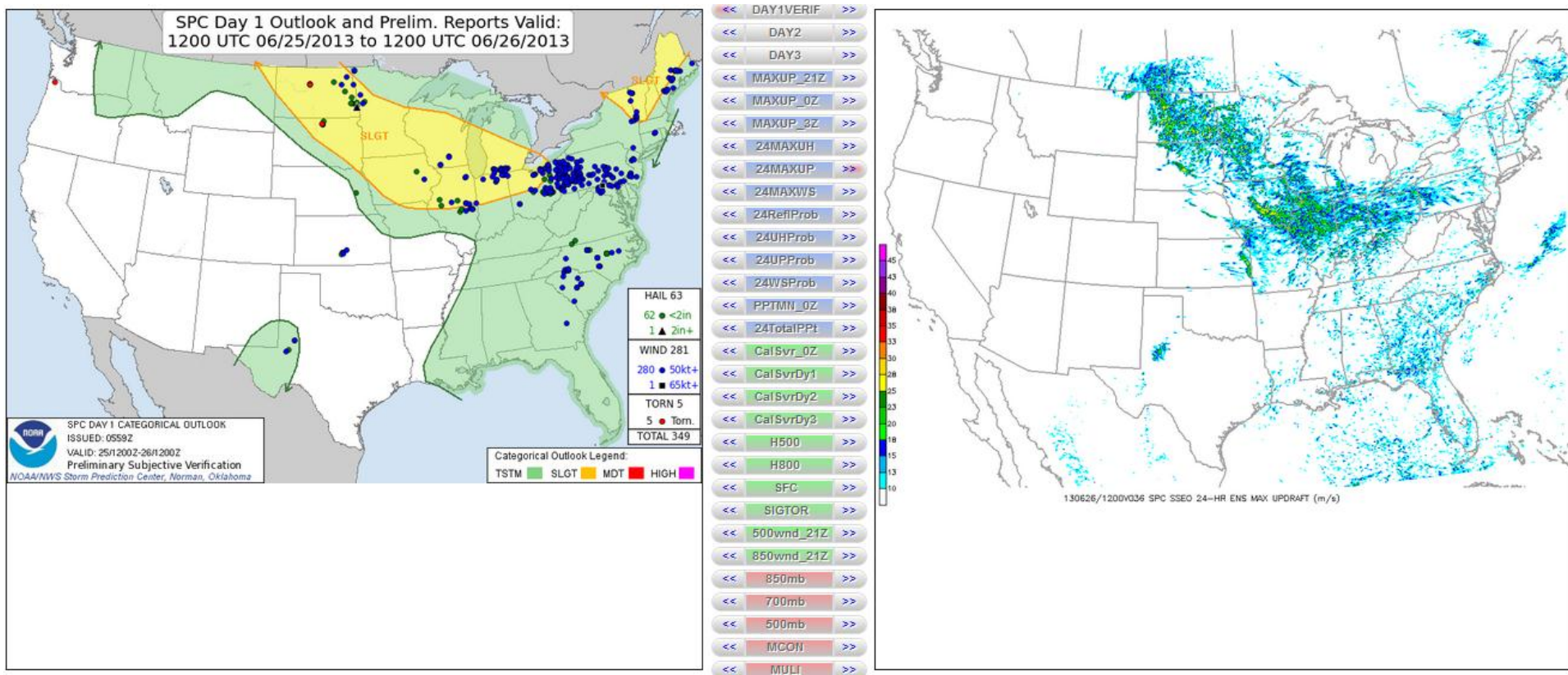
And by the plot of MAX W (and missed by SPC).



- << DAY1VERIF >>
- << DAY2 >>
- << DAY3 >>
- << MAXUP\_21Z >>
- << MAXUP\_0Z >>
- << MAXUP\_3Z >>
- << 24MAXUH >>
- << 24MAXUP >>
- << 24MAXWS >>
- << 24RefiProb >>
- << 24UHProb >>
- << 24UPProb >>
- << 24WSProb >>
- << PPTMN\_0Z >>
- << 24TotalPPt >>
- << CalSvr\_0Z >>
- << CalSvrDy1 >>
- << CalSvrDy2 >>
- << CalSvrDy3 >>
- << H500 >>
- << H800 >>
- << SFC >>
- << SIGTOR >>
- << 500wnd\_21Z >>
- << 850wnd\_21Z >>
- << 850mb >>
- << 700mb >>
- << 500mb >>
- << MCON >>
- << MULI >>



Another example where most of the severe wind reports were outside the area outlooked by SPC, and outside the area of strongest MAX-W from the SSEO



MAX 10-m wind speed has shown some value, but less so than MAX updraft and MAX UH.

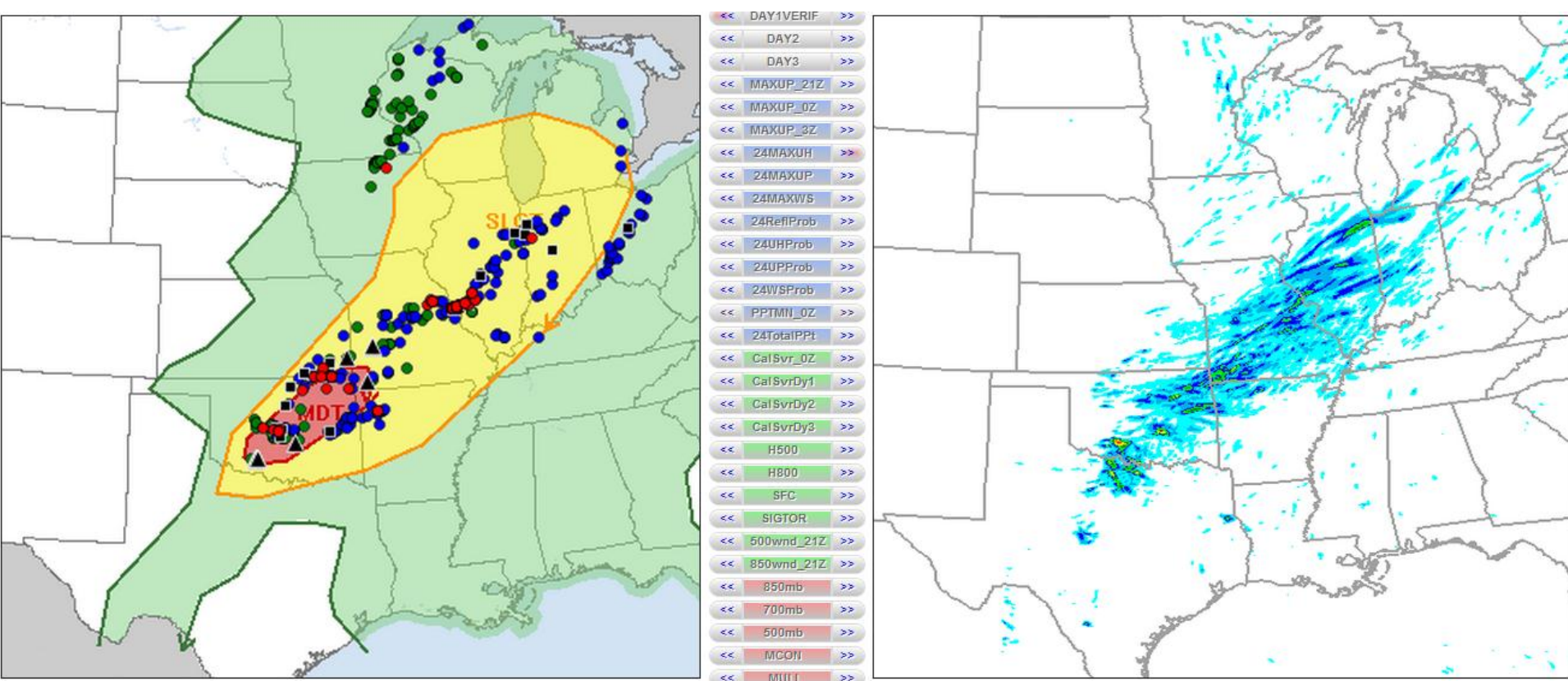
One of the problems with MAX 10-m wind speed is that winds are often high at the surface due to synoptics, without any convection at all.

These storm-resolving models may have other problems with outflow winds, such as:

- 4km resolution may not be good enough to represent the evolution of organized convective systems. Derechos, in particular, remain a theoretical challenge.
- LES boundary layer formulation in these models may inaccurately dampen outflow structures.

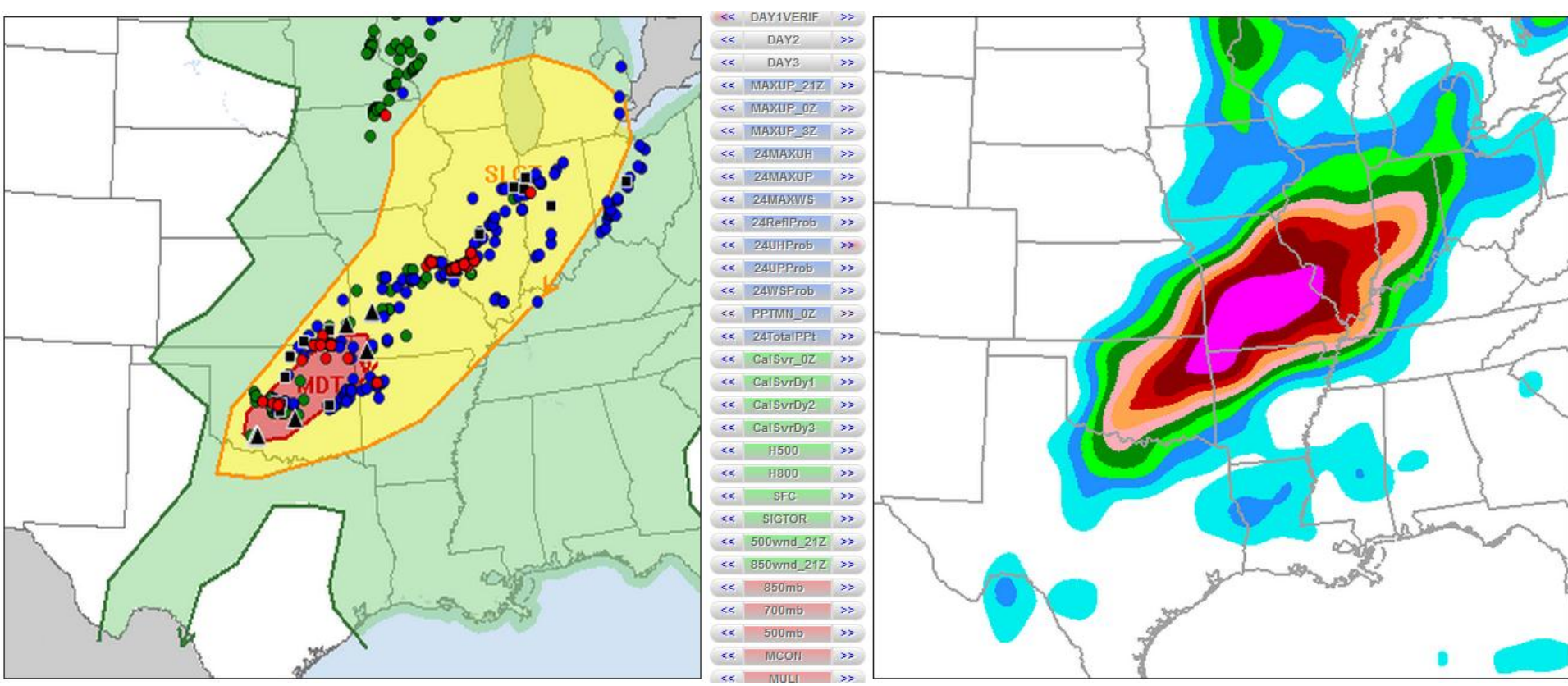
Both MAX and Probability plots can be usefully consulted. In this case, the MAX UH is exceptionally elevated in Oklahoma, which had a tornado outbreak, including a large EF-4 tornado. It was also elevated in Illinois, which also had tornado reports.

Notably, the MAX UH was weaker in central Missouri, an area without tornado reports.



This is the probability of  $\text{MAX UH} > 25 \text{ m}^2/\text{s}^2$  for the same case as the previous slide. This shows a maximum over central Missouri, in contrast to the MAX UH plot. This means most of the models had strong UH over that area. However, areas of strongest MAX UH were a better indicator of the strongest supercells.

By analogy with PPT forecasting, probability plots are like POP, and MAX plots are like QPF.



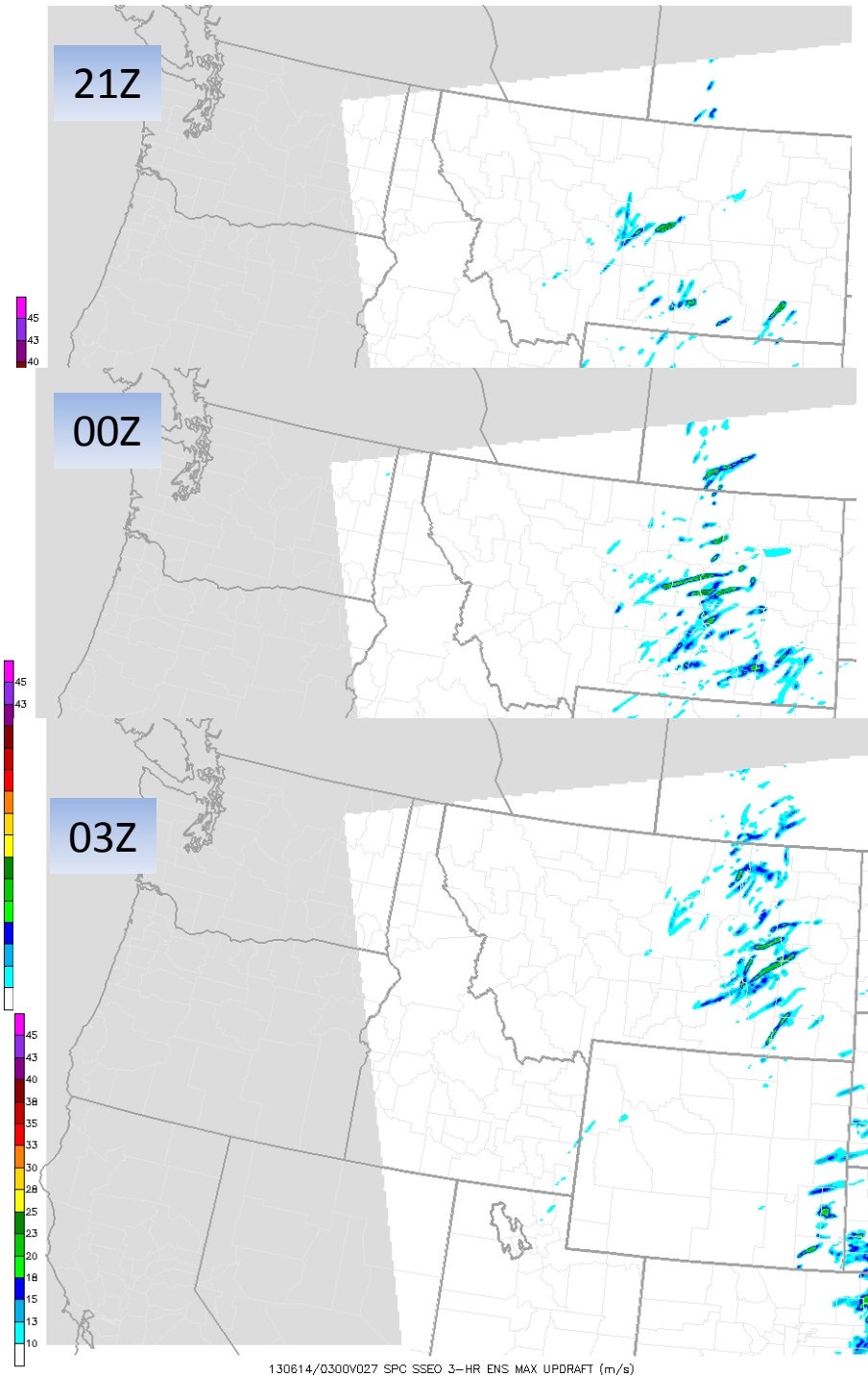
21Z

00Z

03Z

The SSEO is also useful for assessing the timing and movement of severe weather.

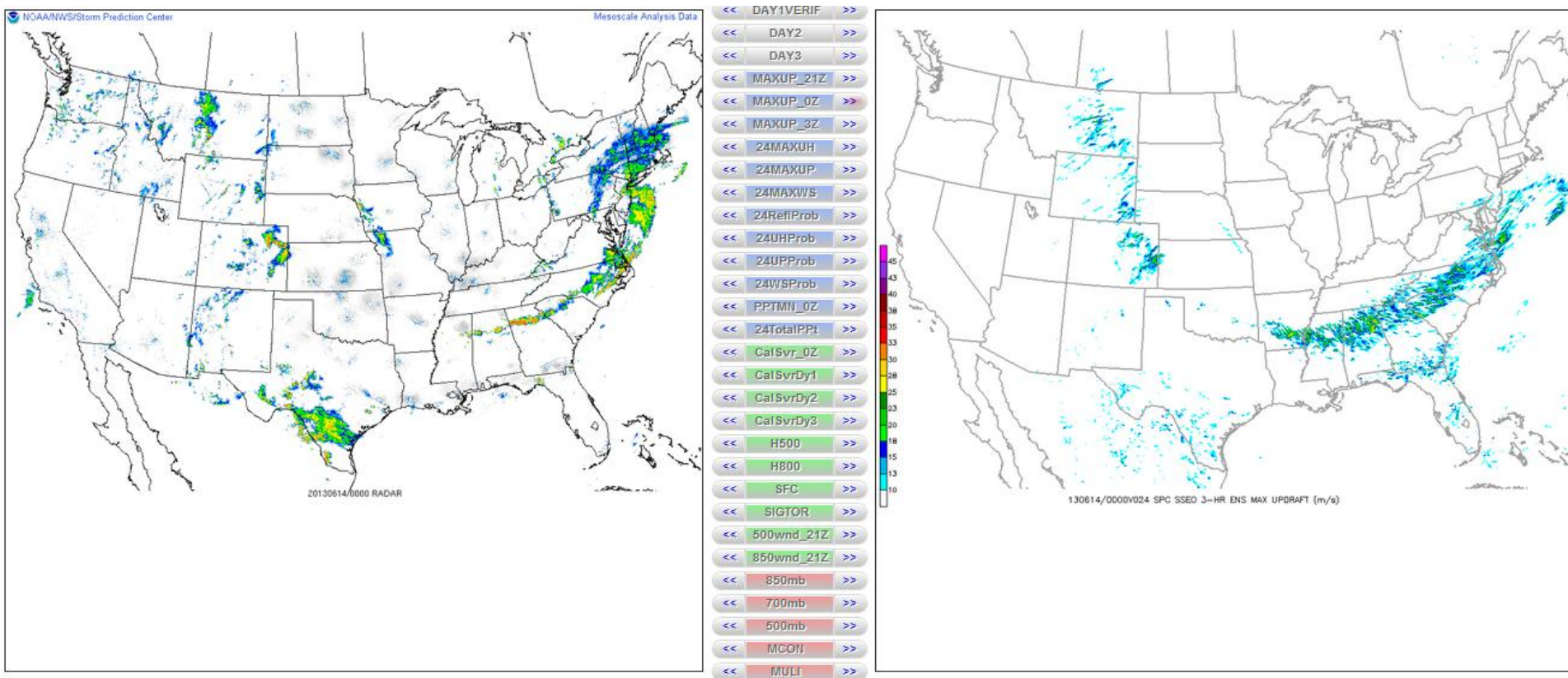
Here we see initiation off the mountains around 21Z, propagating eastward across Montana through 3Z.



Same case as previous slide with radar verification at 0Z.

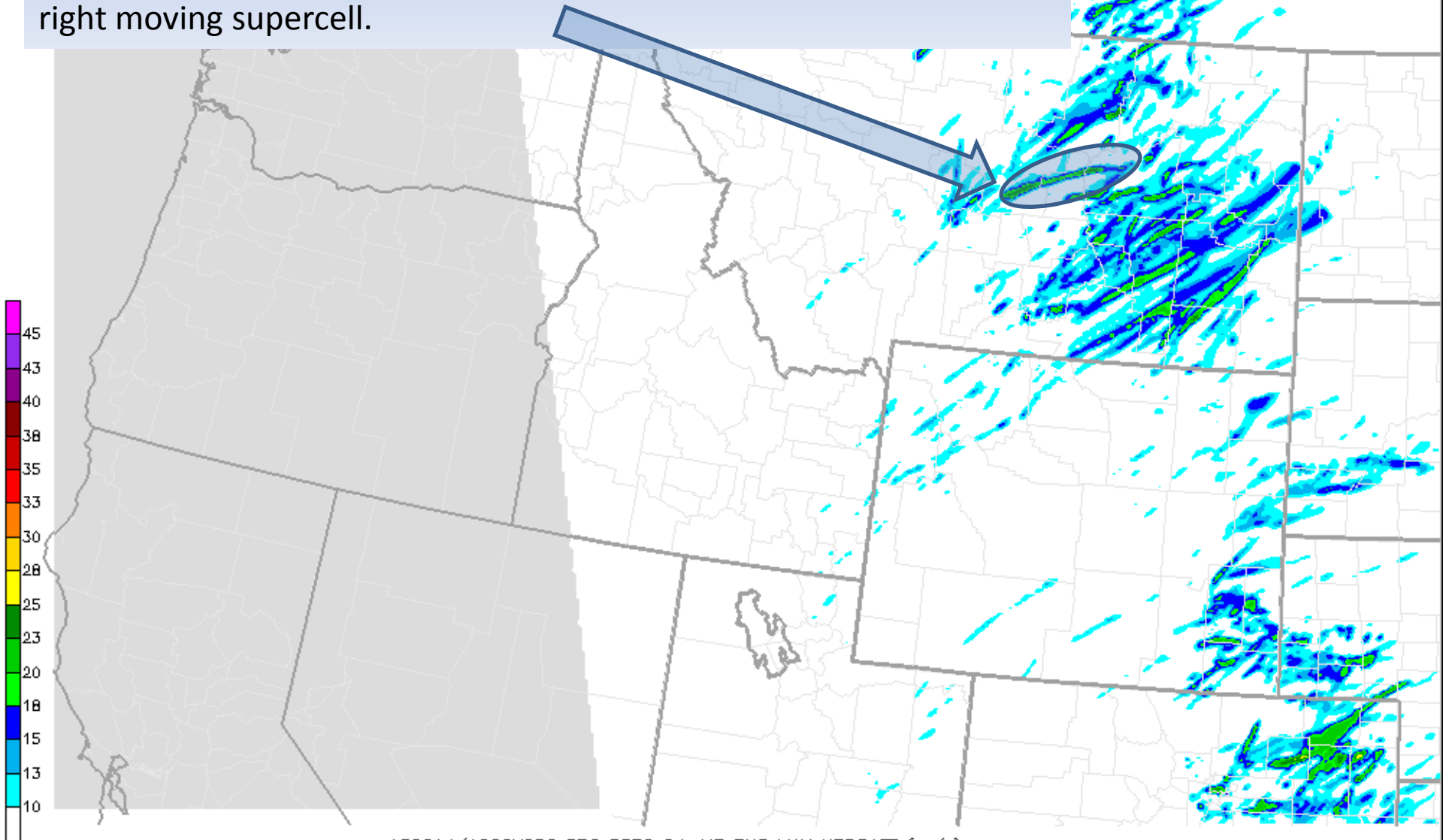
This case had a remarkably good agreement between forecast max updrafts and location, pattern, and timing of areas of convection.

Below shows 0Z radar (left) versus 21Z-0Z max updraft. This was a 30 hour forecast.

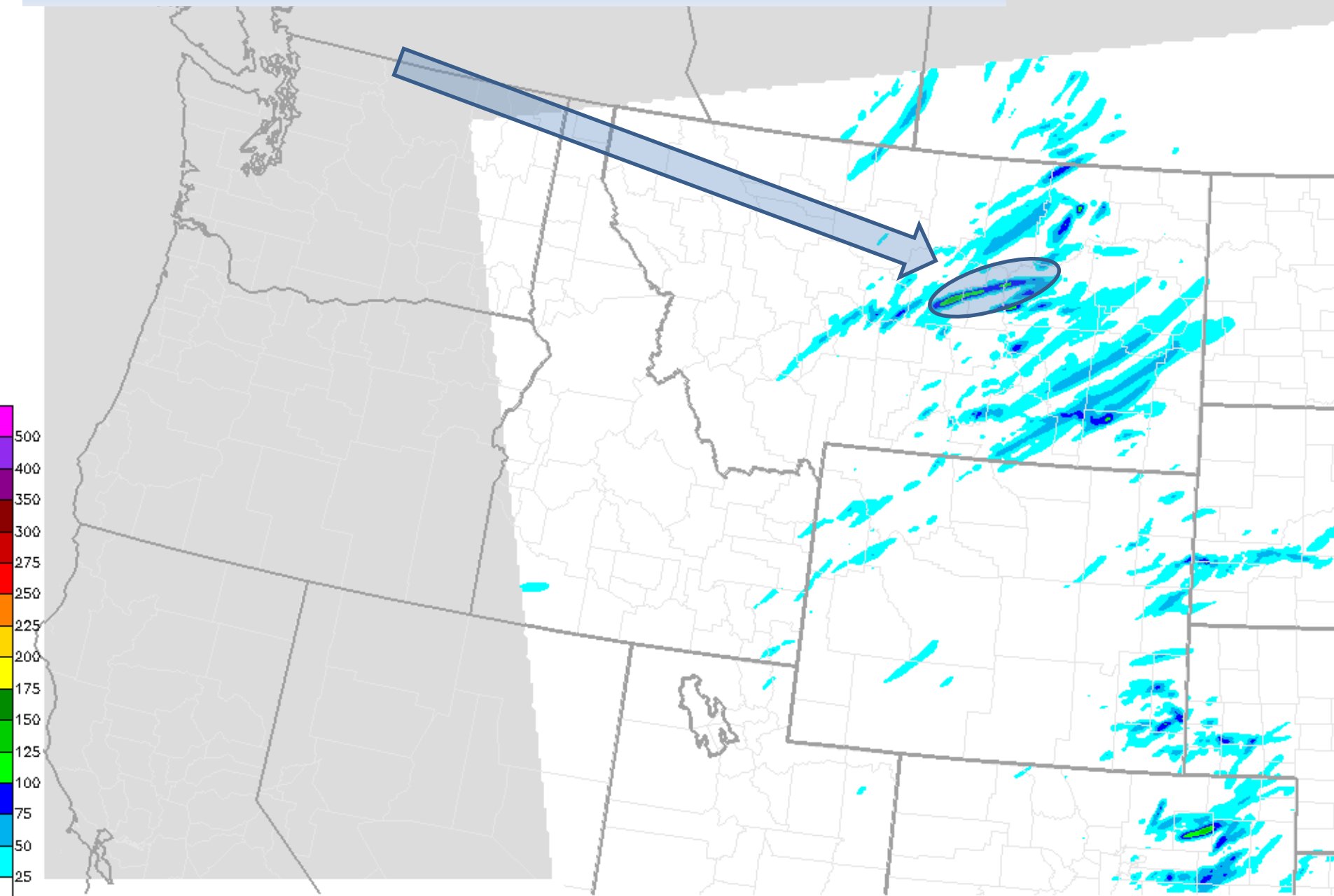


Same case as previous 2 slides, but with 24hour MAX W.

Storm motion vectors can be accurately deduced from 24 hour plots. This shows mostly northeast storm movement, with one notable right moving supercell.

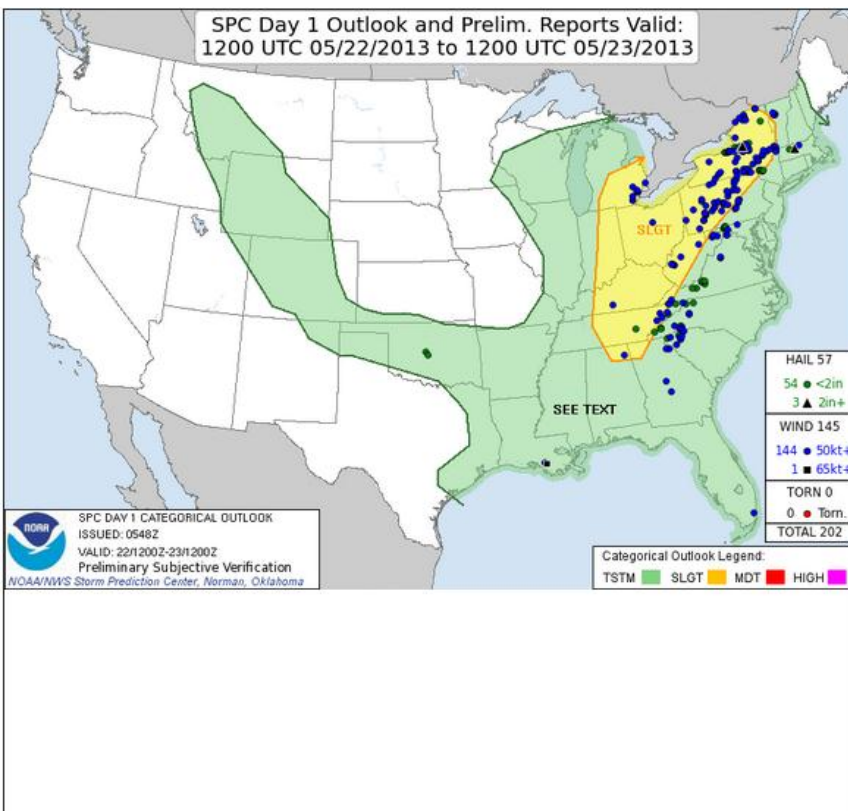


We deduce this was a right mover as the UH was elevated for this cell:

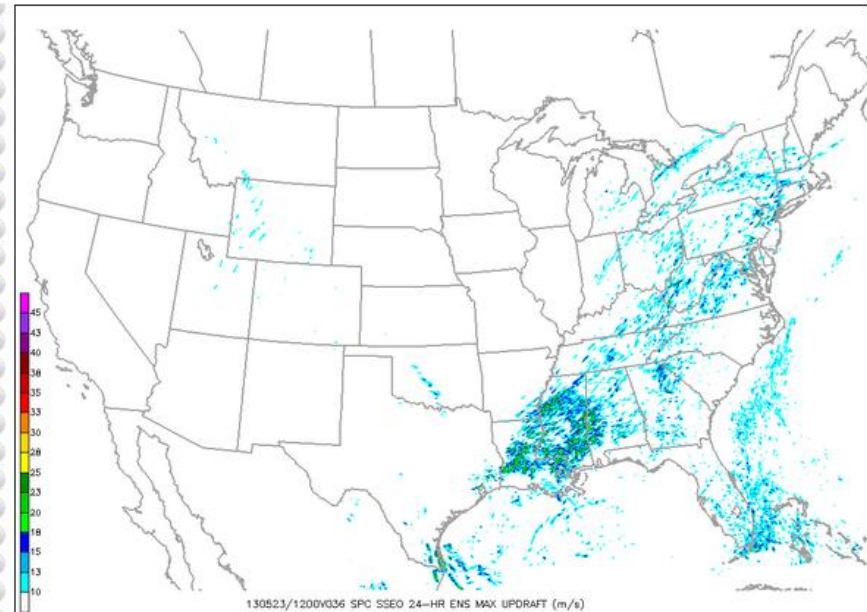


130614/1200V036 SPC SSEO 24-HR ENS MAX UH (m2/s2)

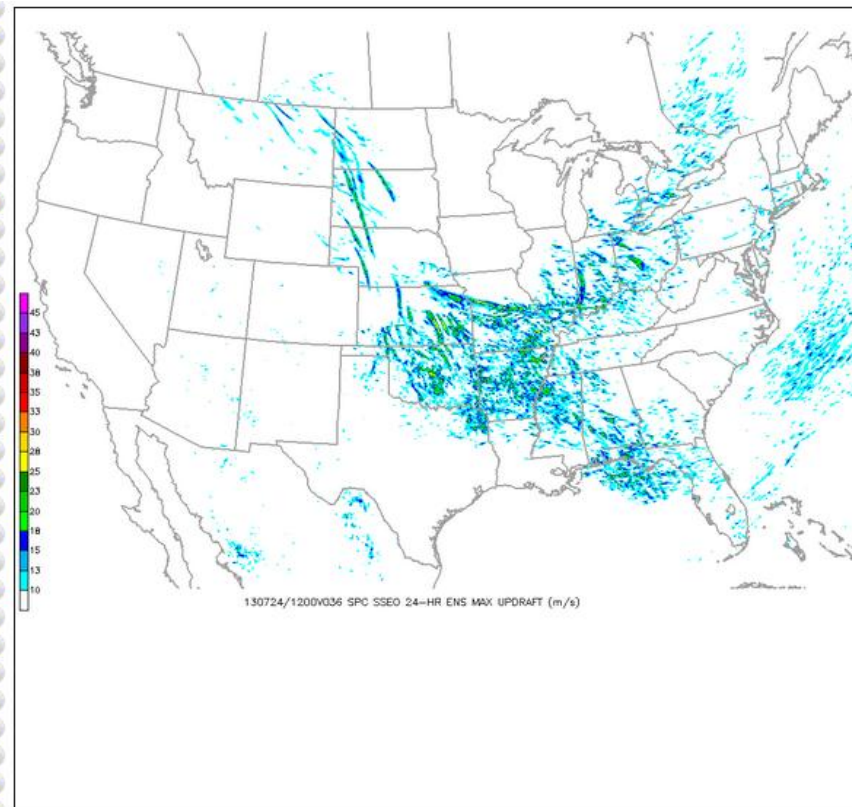
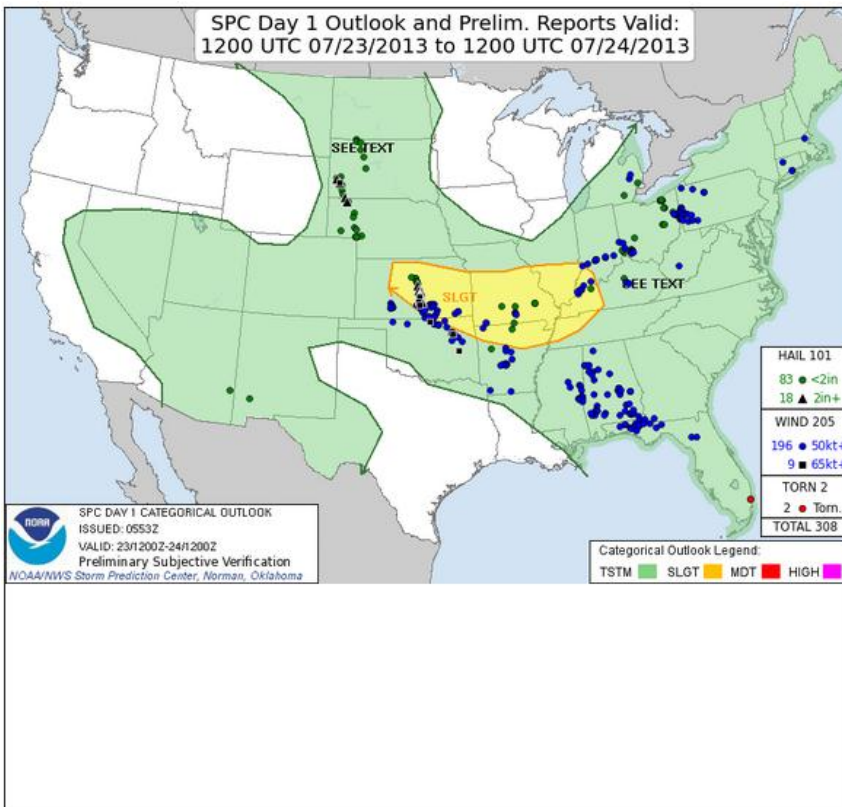
When compared with SPC DAY1 outlooks, the SPC sometimes wins:



- << DAY1VERIF >>
- << DAY2 >>
- << DAY3 >>
- << MAXUP\_21Z >>
- << MAXUP\_0Z >>
- << MAXUP\_3Z >>
- << 24MAXUH >>
- << 24MAXUP >>
- << 24MAXWS >>
- << 24RelProb >>
- << 24UHProb >>
- << 24UPProb >>
- << 24VSPProb >>
- << PPTMN\_0Z >>
- << 24TotalPPt >>
- << Cal Svr\_0Z >>
- << Cal SvrDy1 >>
- << Cal SvrDy2 >>
- << Cal SvrDy3 >>
- << H500 >>
- << H800 >>
- << SFC >>
- << SIGTOR >>
- << 500wnd\_21Z >>
- << 850wnd\_21Z >>
- << 850mb >>
- << 700mb >>
- << 500mb >>
- << MCON >>
- << MULI >>



And sometimes the SSEO wins:



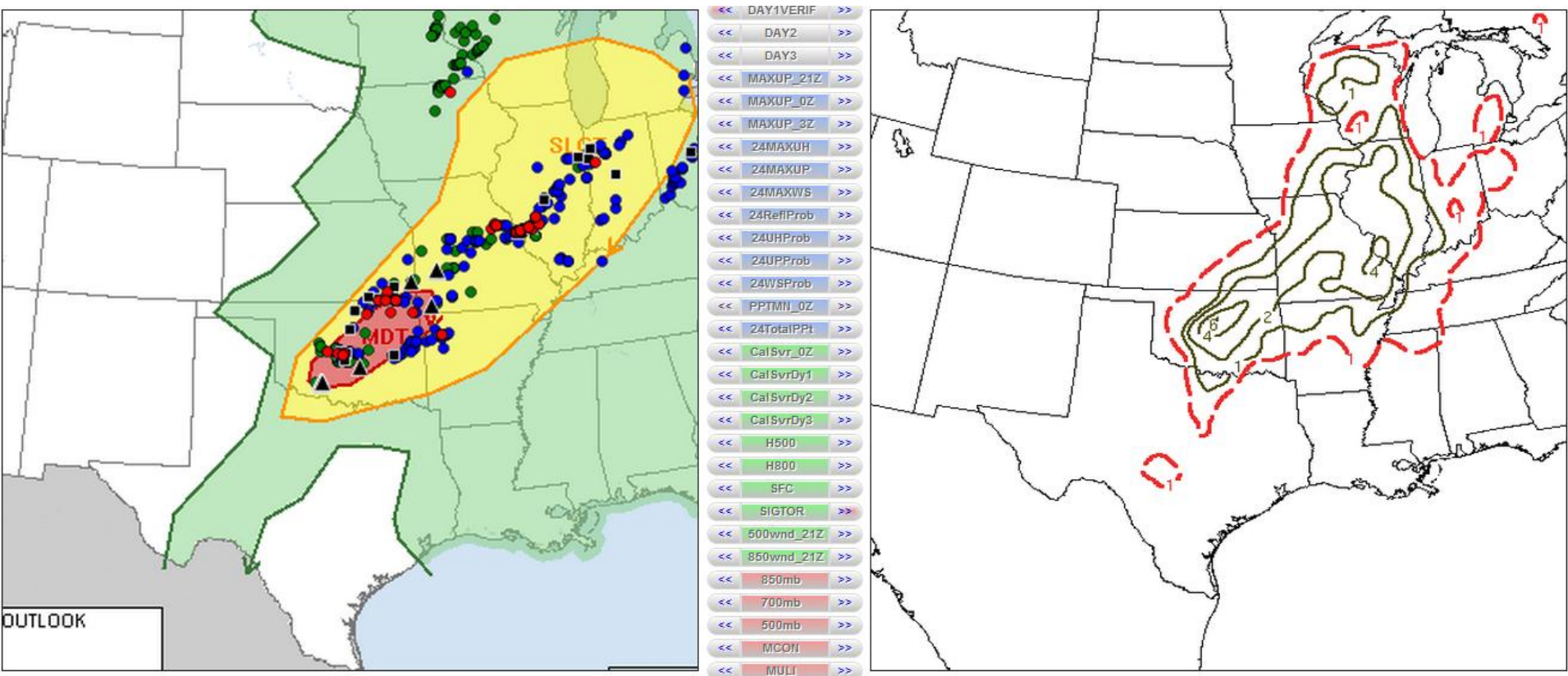
From looking at a lot of these, the SPC DAY1 is generally better than the SSEO indications.

Most commonly, SPC DAY1 and the SSEO are highly correlated.

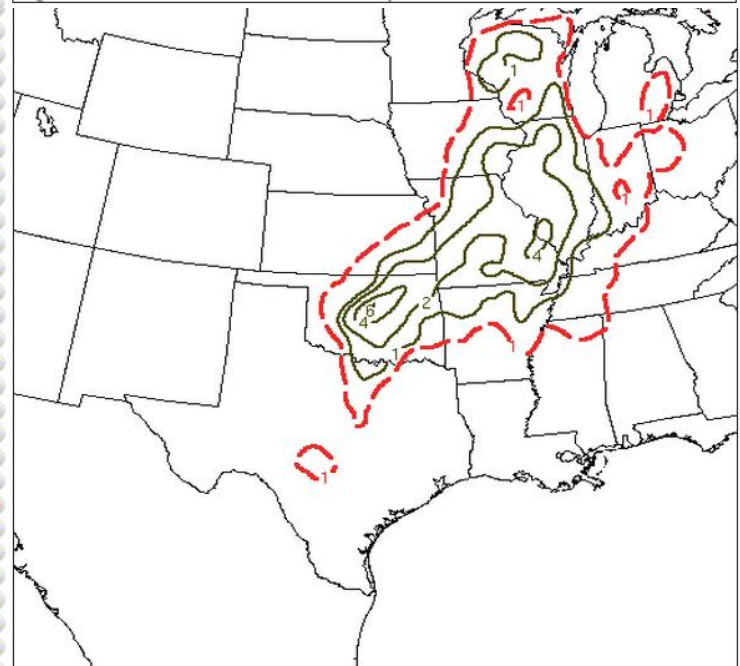
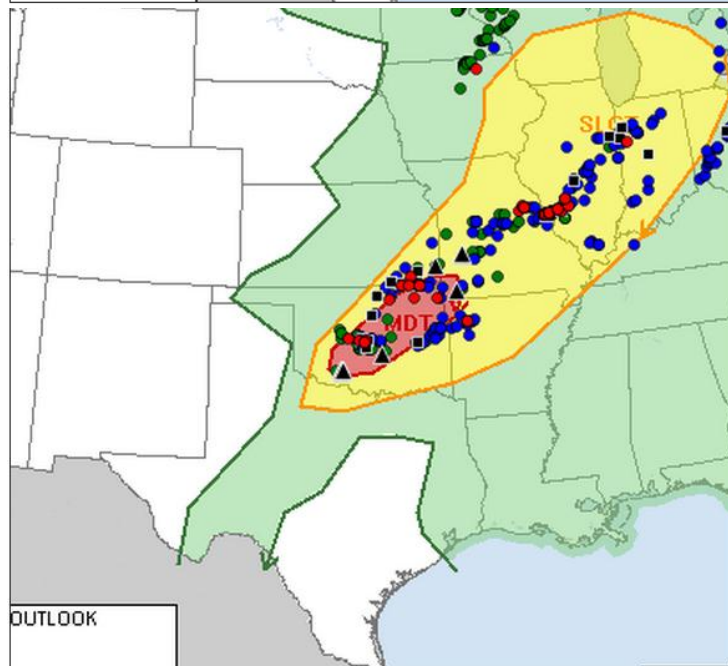
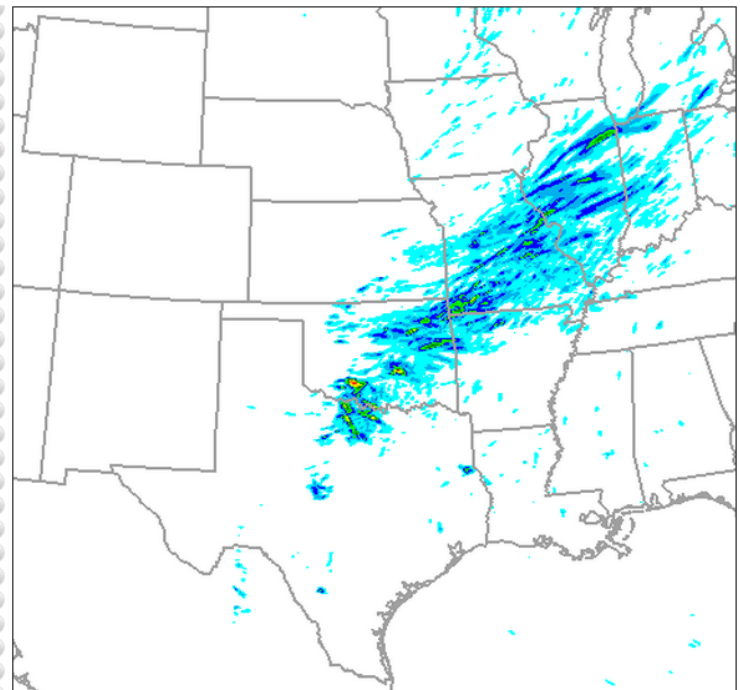
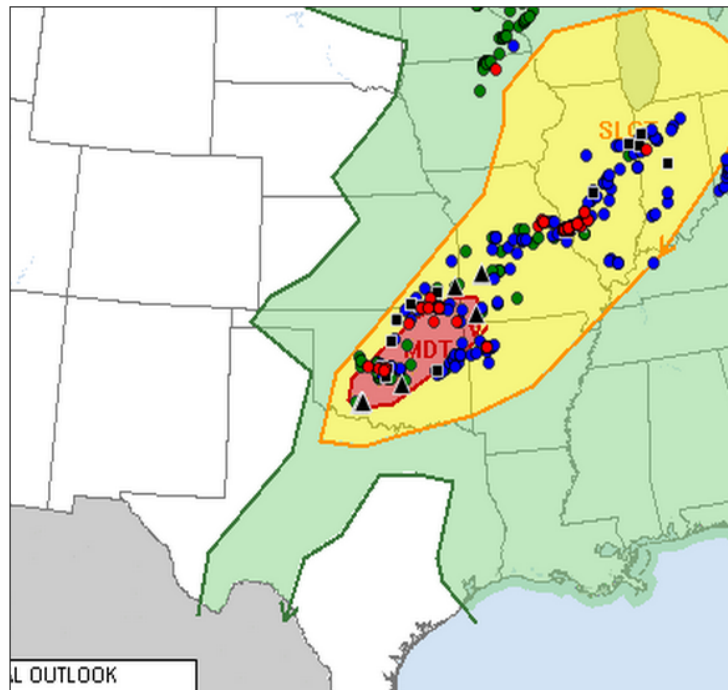
Composite parameters can be problematic. They depend on a few parameters deduced from soundings, and do not account for the great variety of storm structure that convection-resolving models can.

They also can not account for the effects of capping, the influence of clouds, outflow boundary interactions, etc., all of which storm-scale models directly deal with.

For this outbreak case, the SIG TOR parameter from the 3-hour SREF forecast looks pretty good, reaching a maximum value in central Oklahoma where tornadoes were the strongest.



However, the MAX-UH SSEO 24-hour forecast does a better job:

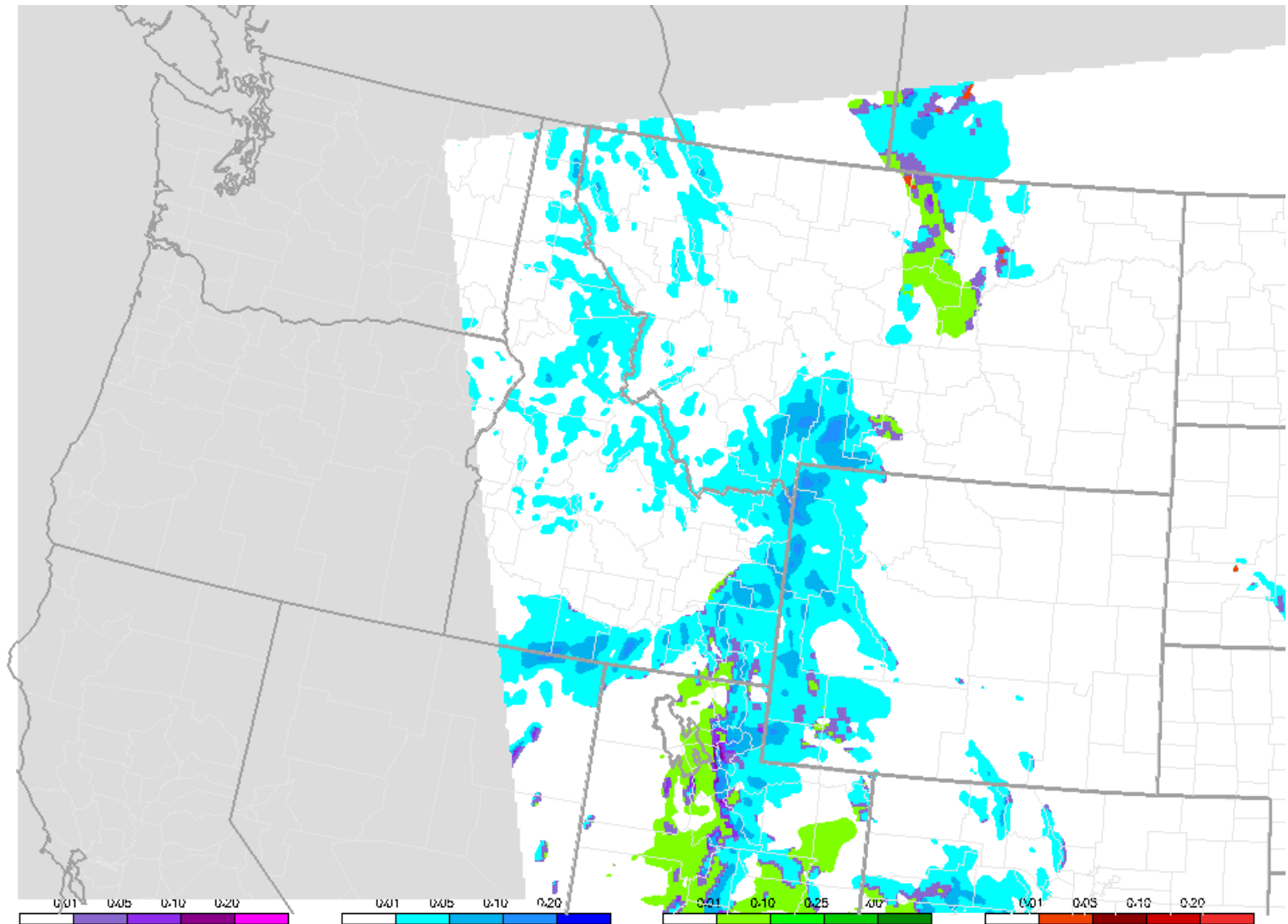


The ability of storm-resolving models to handle vast amounts of complexity potentially makes parameter-based forecasting obsolete.

Of what value is CAPE, if actual updraft strength can be directly determined?

For Winter Weather, the convective forecast elements are not generally useful; however, the SSEO does include 1-hour precipitation, color coded by PPT type.

This is the March 21 2013 forecast for 9Z, showing a forecast of snow and mixed PPT.



130321/0900V033 SPC SSEO 1-HR MN PREC (IN) BY DOMINANT PTYPE - MIX/IP(Pur), SNOW(Blue), RAIN(Grn), ZR(Red)

# The Future for Storm-Scale Ensembles:

- Improved resolution. 4-5km is really borderline for resolving details of convection.
- Improved spatial coverage.  $\sim 1/3$  of the United States is not covered by the ensemble domain.
- longer integration time. Ensemble is only available for DAY1.
- Improvements to model physics and initialization. A prime area for research is to track-down reasons for SSEO misses. These cases can probably be traced to initialization errors (such as the need for more data), or model short-comings. SSE's are already an extremely valuable tool, solving modeling issues would further extend their utility. For example, it is not clear why the SSEO has trouble with high wind events.

# Summary/Findings (1 of 2)

- THE SSEO is the state of the art in forecasting convective weather. It is useful for answering questions of initiation, timing, strength, and kind of severe weather.
- MAX W is the most useful proxy for all kinds of severe weather. MAX UH was also valuable for tornado forecasting. MAX 10-m wind worked sometimes, but was not as useful. Most of the failures of the SSEO to successfully predict severe weather were cases of predominantly straight line winds.
- MAX W was a better proxy for severe weather, by far, than any other forecast method, including composite parameters and things like CAPE and Helicity.
- Combined MAX plots are analogous to QPF, while probability plots are analogous to POP. Both can be useful at times.

# Summary/Findings (2 of 2)

- Individual model realizations do not often verify, that is, the specific storms shown by a model usually do not happen; but the pattern shown by the ensemble is often amazingly good.
- During the forecast process, the SSSEO is so good, that it is tempting to go there first, to see what will happen; however, the SSEO is not perfect, and it is important to understand the broader situation first, and use the SSEO to show you the possibilities.
- However, we often had the experience of not being sure about what to expect for severe weather, but once we saw the SSEO, we had the answer.
- The future would seem to be bright for storm-scale ensembles, which make obsolete parameter-based forecasting.